QUALITY ASSURANCE/QUALITY CONTROL PLAN

BENTHIC BIOLOGICAL MONITORING PROGRAM

OF THE LOWER CHESAPEAKE BAY

July 1, 2010 to June 30, 2011

Approved by:

Daniel M. Dauer, Project Manager
ODU, Biological Sciences

5/21/2010
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Michael F. Lane, QA Officer
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F.A. Hoffman, Project Officer
Virginia, DEQ

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BENTHIC BIOLOGICAL MONITORING PROGRAM

OF THE LOWER CHESAPEAKE BAY

PREPARED BY

DANIEL M. DAUER

DEPARTMENT OF BIOLOGICAL SCIENCES

THE BENTHIC ECOLOGY LABORATORY

OLD DOMINION UNIVERSITY

NORFOLK, VIRGINIA 23529

July 1, 2010 to June 30, 2011

1.0 INTRODUCTION

1.1 BACKGROUND

A five-year EPA study completed in 1982 identified widespread declines in the water quality and living resources of Chesapeake Bay. Federal, state, and local officials recognized the need for environmental management actions to achieve water quality conditions necessary to protect human health and to restore, enhance and protect living resources within the Chesapeake Bay and its tributaries. One of the requirements for sound environmental management is adoption of environmental monitoring to assess the response of water quality and living resources to man-made activities such as environmental management actions as well as sources of natural variability. By measuring these responses, managers can also set limits for and quantify progress towards goals for the restoration of water quality and living resources or provide warnings of potential environmental degradation in advance of serious problems.

The response of aquatic systems like Chesapeake Bay to management actions can be measured using a variety of abiotic and biotic variables which serve as indicators of environmental health. Abiotic variables are generally direct physical or chemical parameters of water quality (dissolved oxygen, turbidity, nutrients, heavy metals, chlorinated and aromatic hydrocarbons, etc.). Measuring these variables is necessary to evaluate and detect sources of pollution and to provide a means for evaluating the effectiveness of control or abatement measures. However, from man's point of view the ultimate evaluation of the environmental and, hence, management actions on any body of water must emphasize living resources.

A wide variety of biotic variables can be measured. Estimates of the benthic macrofaunal community (organisms retained on a 0.5 mm screen) are used to indicate environmental health because benthic animals (1) are relatively sedentary, (2) have relatively long life spans, (3) consist of different species that exhibit different tolerances to stress, (4) are economically important or are important food sources for economically important or recreationally important species, and (5) have an important role in recycling nutrients or other chemicals between the sediment and the water column. Recent reviews of the rationale for pollution monitoring studies have confirmed the importance and priority of benthic biological monitoring in meeting the primary objectives of most marine and estuarine monitoring programs (Bilyard 1987).

As part of the 1987 Chesapeake Bay Agreement, the Benthic Monitoring Program component of Virginia's Chesapeake Bay Water Quality Monitoring Program was established to assist with the evaluation of environmental management efforts within the state of Virginia and within the Chesapeake Bay ecosystem as a whole. When first established, the primary goals of the benthic monitoring program were to assess the current status of benthic biological communities, to identify long-term trends in benthic community structure and relate changes in those communities to changes in water quality. Advances in and modifications to the program including the development of the Benthic Index of Biotic Integrity (Weisberg et al., 1997) and the adoption of a probability based monitoring scheme, have allowed for more direct assessment of changes in

benthic community health over time and as well as the areal extent of benthic communities which do not meet restoration goals.

1.2 OBJECTIVES OF THIS DOCUMENT

This document describes standard operating procedures for all aspects of the Benthic Monitoring Program component of the Virginia Department of Environmental Quality's Chesapeake Bay Monitoring Program. The procedures described below were developed to collect and process samples and meet all of the associated data quality objectives needed to ensure that the data produced meet the objectives of the program.

1.3 ORGANIZATION OF THIS DOCUMENT

This document is organized into 8 Chapters. Chapter 2.0 states the Benthic Program objectives. Chapter 3.0 describes program management, organization, and the areas of responsibility of program personnel. Chapter 4.0 describes the field program including site selection, field measurements, and instrument calibration. Chapter 5.0 provides an overview of laboratory procedures and data quality objectives. Chapter 6.0 describes data quality assurance procedures; it emphasizes data management and simplistic value checks because data quality controls are built into many aspects of the program. Chapter 7.0 provides an overview of standard statistical and graphical analysis techniques as well as standard products included in reports. Chapter 8.0 is a list of references and literature cited.

2.0 OBJECTIVES

2.1 PROGRAM OBJECTIVES

The objectives of the Benthic Biological Monitoring Program of the Virginia Chesapeake Bay Program as presented in this proposal are:

1. to characterize the health of regional areas of the lower Chesapeake Bay as indicated by the structure of the benthic community. These characterizations will be based upon application of the benthic restoration goals and Chesapeake Bay Benthic Index of Biotic Integrity (B-IBI) to data collected by a probability-based sampling design within the lower Chesapeake Bay. A probability-based sampling design allows calculation of confidence intervals around estimates of condition of the benthic communities. Confidence intervals provide managers with full knowledge of the strength or weakness of the data upon which their decisions will be based. In addition, probability-based data allows managers to estimate the actual area (number of acres) throughout the system (e.g., tributaries, areas of concern) in which ecological conditions differ from reference areas.

2. to conduct trend analyses on long-term data at fixed-point stations to relate temporal trends in the benthic communities to changes in water and/or sediment quality. Trend analyses will be updated annually as new data are available.

3. to warn of environmental degradation by producing an historical data base that will allow annual evaluations of biotic impacts by comparing trends in status within probability-based strata and trends at fixed-point stations to changes in water and/or sediment quality.

2.2 DATA QUALITY OBJECTIVES

The quality assurance/quality control (QA/QC) program at the BEL is designed to ensure that data of the highest quality possible for estimates of field parameters are being generated and transferred to the funding agency. The fundamental parameter being measured in any biological monitoring program is what species are present (Ellis 1988). "The fundamental accuracy in biological surveys is getting the species identification right, getting the correct Linnean name, and doing so consistently" (Ellis 1988, p. 507). Indeed, all other estimates of field parameters (e.g., densities and biomass of populations) can not truly be tested for accuracy because standards are meaningless. Accuracy can only be approximated by inter-laboratory calibrations (see e.g. Ellis and Cross 1981) which are not part of the present program because (1) accepted protocols do not exist and (2) fiscal resources are limited.

The QA/QC program is designed to manage sample handling, documentation and custody, proper data generation, and quality control actions. The QA/QC program tracks and monitors the fate of a sample from collection to data submission and analysis assuring that the proper samples have been analyzed by the appropriate methods and that necessary QC measures have been taken to ensure that data of definable quality have been produced.

For all parameters measured a discrepancy of less than 5.0% from reanalyzed samples is considered acceptable, except for estimates of weight, where a discrepancy of less than 2 mg from reanalyzed samples is considered acceptable.

3.0 PROGRAM ORGANIZATION, MANAGEMENT, AND PERSONNEL

3.1 PROGRAM MANAGER

The Program Manager (PM), Dr. Daniel M. Dauer, is responsible for the overall supervision of activities associated with the project. The PM conducts regular staff meetings with all personnel to discuss the progress of the program, problems encountered, report preparation and any other matters that affect the successful continuation of the program. The PM reviews the overall results of the analyses and approves the quality assurance/quality control (QA/QC) protocols to insure the quality of the results. The PM administers the financial and technical aspects of the program at the BEL. The PM is responsible for the review and submission of all data products transmitted to the contracting agency. The PM or his representative participates in meetings, workshops, and coordinating sessions with the contracting agencies.

3.2 LABORATORY SUPERVISOR

The Benthic Ecology Laboratory Supervisor (BELS), Mr. Anthony J. Rodi, Jr., is responsible for all aspects of the sorting, identification, and enumeration of macrobenthic taxa collected in the samples. The BELS is responsible for all aspects of the analysis of sediment samples for particle size distribution and total volatile solids. The BELS is responsible for implementing all of the appropriate laboratory QA/QC procedures, maintaining supplies and equipment necessary for analyses, and training of all lab and field personnel. The BELS is also the chief scientist for the BEL field operations, supervising all aspects of field work and validating data as it is generated. As chief scientist the BELS ensures that all field activities transpire within BEL policies, guidelines and protocols, and has ultimate decision-making authority over all technical and logistical matters which arise during sampling events. The BELS reports to the PM.

3.3 DATA ANALYST

The Data Analyst (DA), Mr Michael F. Lane, performs routine statistical analyses to investigate the current status of and long-term trends in water quality and living resource conditions in Chesapeake Bay and its tributaries and maintains long-term SAS data sets in support of analytical efforts. The DA also performs statistical analysis and literature searches to establish linkages between water and habitat quality, living resources and pollution control efforts in the Chesapeake Bay, assists in the production of reports, publications, and presentations related to Chesapeake Bay Program issues and represents ODU's Chesapeake Bay Program at various regional, state and federal meetings related to Chesapeake Bay Program data analysis activities. The DA reports to the PM.

3.4 QUALITY ASSURANCE MANAGER

The QA Manager (QAM), Mr Michael F. Lane, is responsible for ensuring the implementation of all the Quality Assurance/ Quality Control (QA/QC) procedures. The QA Manager verifies that the QA/QC protocols and standards are applied to all work to assure that the results obtained are of the type and quality needed and expected. The QA Manager is responsible for maintaining the official, approved QA Project Plan. The QA Manager works closely with the Field Operations Chief and the Data Manager, and reviews field sampling plans and QA/QC data outputs. The QA Manager also serves as Laboratory Manager, overseeing day-to-day operation of the Laboratory QA/QC Program for the BEL. The QAM reports to the PM.

3.5 RESEARCH ASSISTANTS (RA)

Research assistants are responsible for performing field measurements; sample collection, handling, transport, and storage; and data logging, reduction and transmittal. Research Assistants are responsible for performing all duties within the BEL QA/QC guidelines protocol. RAs report to the BELS.

3.6 LABORATORY ASSISTANTS

Laboratory Assistants (LA) are responsible for assisting in the collection and preparation of samples and data entry and processing. The LAs also participate, under supervision, in some of the routine analytical procedures. LAs report to the BELS.

3.7 TECHNICAL STAFF FOR EACH AREA OF RESPONSIBILITY QUALIFICATIONS

Dr. Daniel M. Dauer, Program Manager, has over 30 years of professional experience in marine benthic ecology, environmental assessment using macrobenthic community structure, functional morphology and behavior of surface feeding benthos and the systematics and ecology of polychaetous annelids. Dr. Daniel M. Dauer has 82 papers published or in press, has published 143 Technical Reports, has 133 grant and contract awards totaling **$20,446,458** including awards as a Co-Principal Investigator, has made 279 presentations at scientific meetings or invited seminars, and hosted three professional society meetings. Dr. Dauer's applied marine research emphasizes the use of benthic (bottom-dwelling) communities in environmental impact assessment. He has successfully directed the Benthic Monitoring Program for the Department of Environmental Quality since 1985. Research programs conducted by Dr. Dauer have played a key role in such environmental issues as the placement of open ocean disposal sites, dredging of the major ship channels of the lower Chesapeake Bay and determining the health of the biota of the entire lower Chesapeake Bay and its major tributaries as part of the cleanup effort of the Chesapeake Bay Restoration Program. This research is an important local and regional service to environmental regulatory and management agencies and has received funding from the Army Corps of Engineers, National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, Virginia Water Control Board, Virginia Commission of Game and Inland Fisheries, Virginia Port Authority, Virginia Department of Highways and Transportation and a variety of private firms. Dr. Dauer is experienced in data analysis of benthic community structure including univariate and multivariate analyses.

Mr. Anthony J. Rodi, Laboratory Manager, holds a Master of Science degree in Biological Sciences from Old Dominion University and has extensive training in the identification of benthic invertebrates from the Chesapeake Bay, Gulf of Mexico and continental shelf of the East Coast of the United States. He is expert in the systematics of all major invertebrate phyla of marine, estuarine and freshwater habitats. Mr. Rodi has been the Benthic Ecology Laboratory Manager for the last 10 years supervising all employees and training staff in the standard operating procedures of the laboratory. He has over 20 years experience as the Chief Scientist on over 75 research cruises, supervising all field collection activities. He also has expertise in data handling, data verification, data transmission and submittal, and data management having produced over 35 technical reports electronically.

Mr. Michael F. Lane, Data Analysis, holds a Master of Science degree in Biological Sciences from Old Dominion University and has over 15 years experience in data analysis, data management, SAS statistical programming and graphics production. He has an excellent understanding of multivariate and univariate statistical analytical procedures and statistical

design. Mr. Lane has authored and/or co-authored many technical reports for both state and federal agencies, several articles for scientific publications, and presentations for various scientific meetings. Mr. Lane has represented Old Dominion University's monitoring programs during committee and workgroup meetings related to data analysis procedures for over 10 years.

4.0 FIELD PROGRAM

The field program is supervised by the Laboratory Manager and consists of four phases of activity involving all types of sampling: (1) site selection, (2) cruise preparation, (3) sampling cruise, and (4) post-cruise. Samples are collected during the B-IBI summer index period - July 15th through September 30th . With the exception of site selection, all phases of the field program occur within this summer index period.

4.1 SITE SELECTION

The monitoring program currently samples both fixed and probability-based sites. Fixed sites are used to assess long-term trends in benthic community condition in specific regions of each tributary and the Chesapeake Bay main stem while probability-based sampling sites are used to assess the spatial extent of benthic community degradation and identify potential sources of that degradation at different spatial scales.

4.1.1 Fixed Sites

Twenty one fixed-point stations in the lower Chesapeake Bay are currently sampled as part of the Benthic Biological Monitoring Program of the Chesapeake Bay Program. Stations are located in the mainstem of the Bay and within the major tributaries - the James, York and Rappahannock Rivers (see Figure 1). Stations coordinates are listed in Table 1. In the tributaries, stations are located within the tidal freshwater zone (TF5.5, TF4.2, TF3.3), the turbidity maximum (transitional) zone (RET5.2, RET5.2B, RET4.3, RET3.1), the lower estuarine mesohaline mud zone (LE5.4, LE4.1, LE3.2, LE3.4) and the lower estuarine polyhaline silty-sand zone (LE5.4, LE4.3, LE4.3B). In the mainstem of the Bay three stations are located off the mouths of the major tributaries (CB8.1, CB6.4, CB6.1) and two stations in the deeper channels near the Bay mouth (CB7.3E) and above the Rappahannock River (CB5.4). All of the above stations have been sampled since March 1985, with the exception of Stations RET5.2B, LE4.3B and LE3.4 which have been sampled since September 1988. In March 1988, two stations were added in the Southern Branch of the Elizabeth River (SBE2, SBE5). Fixed-point benthic monitoring stations were selected to represent regions of the lower Chesapeake Bay that are different in major factors, such as water circulation and salinity that affect ecological processes.

4.1.2 Probability Sites

Probability-based sampling within selected strata is used to supplement data collected at fixed-point stations. Because of the emphasis on development of tributary-based strategies for improvement of the Chesapeake Bay, four strata are sampled - (1) the James River, (2) the York River, (3) the Rappahannock River and (4) the Virginia portion of the main stem of Chesapeake Bay (Figure 2). A total of 25 samples are allocated to each stratum in order to produce a 95% confidence interval of ±10%. Sampling design and methodologies for probability-based sampling are based upon procedures developed by EPA's Environmental Monitoring and Assessment Program (EMAP, Weisberg et al. 1993) and allow unbiased comparisons of conditions (1) between strata of the lower Chesapeake Bay within the same collection year and (2) within tributaries for data collected between different years. The consistency of sampling design and methodologies for probability-based sampling between the Virginia and Maryland benthic monitoring programs allows bay-wide characterizations of the condition of the benthos for the Chesapeake Bay**.**

4.1.2.1 Sampled Area Definition

The primary requirement for comparability of area estimates among years is that estimated area boundaries be constant. Stratum definitions and sample allocation schemes may be altered provided the same area is covered. Although the precision of the estimate may change depending on the nature and magnitude of the stratification changes, estimates will be comparable from year to year.

Although some boundaries of the Virginia Chesapeake Bay are clear, others are poorly defined. Jurisdictional boundaries such as the Washington D.C.-Maryland line in the Potomac and the Virginia-Maryland line dividing the Chesapeake Bay, Tangier Sound, and Pocomoke Sound are clear. However, sampling limits on Bay and tributary margins are most often controlled by practical considerations such as the draft of the sampling vessel. The upstream distance sampled in tributaries is often subjective because heads of tide are not well known.

4.1.2.2 The Land-water Interface at Bay and Tributary Margins

The Virginia Benthic Monitoring Program samples all bottom areas of the Chesapeake Bay and its tidal tributaries deeper than 1 m MLLW. MLLW is the most prevalent datum in use. It is the 19-year mean for the lower of the two daily low-tides occurring in areas with semi-diurnal tides, such as the Chesapeake Bay. All tidal bottom areas are subject to sampling except for areas restricted by the government. Navigation charts warn of unexploded ordinance in these areas which, therefore, are unsuitable for benthic sampling. On a smaller scale, cable and pipeline areas designated on nautical charts are also avoided.

4.1.2.3 Tributary Head Sampling Limits

The objective is to sample as far up each tributary as the uppermost point at which tidal influences occur (“head of tide”) or as close to it as possible. Accordingly, the farthest point

sampled up each tributary is the head of tide, or the navigable limit according to nautical charts, which ever is closer to the Bay.

4.1.2.4 Probability Site Selection Process

For each sampling stratum 30 sites are selected for sample collection to ensure that 25 samples are collected at random as follows:

1) For each stratum, the Versar GIS Coordinator selects up to 1,000 points at random in a uniform distribution from an area that is a superset of the stratum, using the program written specially for the purpose. Decimal degree reference coordinates are used with a precision of 0.000001 degrees (approximately 1 meter) which is a smaller distance than the accuracy of positioning; therefore, no area of the bay is excluded from sampling and every point in the Maryland Bay has a chance of being sampled.

2) The GIS image of the stratum is overlayed on the selected points and points on land are eliminated.

3) The first 50 selected points are plotted on navigation chart look-alikes and provided to the BELS together with a list of coordinates.

4) The BELS eliminates any of these points which either (a) are in prohibited areas, (b) are clearly shallower than 1 m MLLW, (c) are close to submerged cables or other obstacles, or (d) cannot be approached because of intervening shallow waters. If less than 30 sites remain after this process, additional sites are plotted until 30 sites are selected.

5) Thirty potential sampling sites are now available in each stratum. The selection order of each site is known and stored along with the coordinates.

4.2 CRUISE PREPARATION

4.2.1 Vessel, Crew, and Scientific Party Scheduling/Maintenance

The BELS coordinates all activities associated with cruise preparation as well as vessel, vehicle and supply procurement. All vessels and vehicles used are the property of Old Dominion University's Department of Biological Science or the Department of Ocean, Earth and Atmospheric Sciences. Vessel and vehicle maintenance is the responsibility of either the BELS or the department that owns them.

4.2.2 Site Identification

The Versar Inc. GIS Coordinator provides the BELS with a file containing the top 30 probability site selections for each stratum and stations names are assigned by the BELS. Station names consist of six-character alphanumeric code in which the first two digits represent the year of

collection (e.g. 1994=01, 1995=02, etc.). The third character is a letter representing the stratum in which the sample is collected such that R=Rappahannock River, Y=York River, J=James River and M=Virginia Bay Mainstem. The last two characters are numbers that represent the sites from 1 to 25 in sequential order from south to north. Numbers above 25 indicate that one or more probability sites could not collected for some reason (e.g. depth too shallow). Sample numbers above 25 are based simply on the selection order.

The data file contains latitude and longitude coordinates which the BELS uses to plot station locations on navigational charts using Maptech's Chart Navigator v 4.5 charting software. These navigational plots assist the BELS both to locate the stations and plan transport and logistical support of each cruise. The Versar Inc. GIS Coordinator also provides a series of printouts of maps used to verify station locations produced using the navigational chart software.

4.2.3 Label and Field Data Sheet Production

The BELS coordinates the production of all sample labels, data sheets, and any other required paperwork electronically.

4.2.4 Equipment Coordination

The BELS ensures that all necessary instruments, sampling gear, and equipment are available and in good working order and that all instruments are calibrated on a regular basis.

4.3 SAMPLING CRUISE

4.3.1 Station Location

Stations are located using a differential Global Positioning System accurate to within 10 m. The WQS84 coordinate system (practically equal to NAD83) is currently used. At fixed sites where depth and habitat type have been defined (Table 1), the BELS verifies that location is correct.

4.3.2 Sampling Failure

At probability sites, it may not be possible to collect a benthic sample if the water depth is to shallow water, there are navigation obstacles or the nature of the bottom sediments prevents sample collection (e.g. oyster reef or shell hash). In the first two cases, sampling will be attempted at least once before the site is discarded. In the case of problems with bottom sediments, three attempts at relocation will be made at 20 m to 30 m distances from the original point in different directions before the site is discarded.

Collection may also be prevented due to the failure of navigation or hydrographic instrumentation which may result in loss of ancillary data. In the case of an instrumentation or navigation problem the site will be resampled after equipment is repaired. Only in extreme circumstances where overall success of the program is jeopardized, can a sample be substituted for logistical reasons.

An example would be dropping a single sample six hours travel time up a tributary, collection of which threatened to prevent sampling several other sites because the end of the Index Period deadline was approaching.

4.3.3 Water Column Measurements

Bottom salinity, temperature and dissolved oxygen are measured in-situ at each station with a YSI Model 85 meter and recorded on the Field Data Sheets. All measurements are taken at a depth of one meter above the sediment surface. The YSI 85 meter is calibrated against a standard salinity solution and corrections calculated according to manufacturer's instructions prior to each cruise. The YSI 85 meter is also field calibrated each day of the collection cruise prior to reaching the first sampling station of the day. All procedures follow the manufacturer's instructions.

4.3.4 Macrofaunal Samples

Three samples are collected for benthic community analysis at each fixed site and a fourth is collected as an archive sample. Fixed site samples are collected using a spade-type box coring device consisting of a rectangular corer (10.5 cm X 17.5 cm X 35 cm) with a hinged cutting arm which seals the box sample *in situ*. Each box core sample has a surface area of 182 cm^2 and a minimum depth of penetration of 25 cm. One sample is collected at each probability site using a Young grab with a sample area of 0.04m^2.

All replicates are handled and processed separately. Samples are transferred to a 0.5 mm sieve bucket. The bottom of the sieve bucket is immersed in a 30 gallon trash can filled with ambient water, and shaken and swirled to suspend the larger material, allowing fine sands, silts and clays to pass through the sieve screen. The residual material on the sieve screen is washed into cloth bags pre-labeled with indelible ink. After sieving, the screen is inspected for any organisms not washed into the bag. Any such organisms are removed with dissecting forceps and placed into the appropriate cloth bag. Samples are fixed in a 10% buffered ambient water-formalin solution. A 1% solution of rose bengal stain is premixed into the formalin solution.

For depth distribution analysis, one of the four box core samples is partitioned as follows: 0-5 cm and 5-25 cm. A metal box with horizontal slits on one side at the desired interval is used to partition this replicate. The slit is covered with adhesive tape prior to sampling. After collection of the sample, a flat metal plate is pushed through the slit at the 5 cm depth interval. Each depth fraction is sequentially removed from the bottom of the box into pre-labeled plastic buckets. Each depth-interval sample is handled and processed individually as described above.

4.3.6 Sediment Subsamples

An 8 dram subsample of the surface sediment is taken from the archived replicate prior to sieving at fixed-point stations and from the second grab sample at probability-based stations. Each 8 dram sample is placed into pre-labeled plastic self-locking bags with the station number and date. The sediment subsamples are stored on ice for transport to the laboratory. If there is a marked visual

change in sediment between replicate box core samples at a station, additional sediment subsamples are taken.

4.4 FIELD SAMPLING CHAIN OF CUSTODY

Field labeling procedures of the BEL are designed to ensure that parameter estimates from field collected samples are associated with the proper field collection site. All sample residues for benthic community analyses are washed into pre-labeled cloth bags. Each bag label consists of a code that identifies the sample as collected (1) from one of the three tributaries or the mainstem, (2) the collection site within the tributary or mainstem and (3) the replicate number. All samples from a particular tributary or the mainstem or probability-based stratum are placed into 5 gallon plastic buckets that are pre-labeled with a tributary or mainstem code. After each sampling station is completed the bucket is sealed. After all stations of each tributary or the mainstem or probability-based stratum are sampled the bucket is sealed and stored below deck until off loaded at the end of the cruise.

The archived sampled is handled as above except that all archived samples are placed into a separate 5 gallon bucket that is pre-labeled to record the date of the cruise. Cruise dates are not indicated on the pre-labeled bags or buckets for the non-archived replicates. All replicates from one year are completely analyzed prior to the next year and the same pre-labeled bags and buckets are reused. All of the above information is recorded on the Field Data Sheets for each sampling station.

Sediment samples for particle size and total volatile solids analysis are placed into pre-labeled plastic bags that use the same labeling system as above. New pre-labeled bags are used for each cruise. All sediment samples are completely analyzed prior to the next cruise and used sample bags are discarded.

The chief scientist is responsible for ensuring that all samples are (1) placed into the proper pre-labeled bags, (2) into the proper pre-labeled sealed buckets, and (3) securely stored on shipboard. On return of the vessel to the dock the chief scientist is responsible for the loading of all samples onto the trucks, the transportation of the samples to the BEL and the storage of the samples in the BEL immediately upon arrival at the BEL.

4.4 FIELD SAMPLING DATA QUALITY OBJECTIVES

The Chief Scientist is responsible for (1) visual inspection and decision of acceptance of each sample collected, (2) assuring that each replicate is placed onto the proper pre-labeled collection bag, (3) assuring that bags from each station are placed into the properly labelled plastic bucket, (4) assuring that each sediment sample is placed into the properly pre-labeled plastic self-locking bags and properly stored on ice on the vessel, (5) assuring that additional sediment samples are collected if sediment type changes visually between replicate samples, (6) assuring that the Field Data Sheets are appropriately completed and filed, (7) assuring that all field equipment is properly calibrated and necessary maintenance is performed, and (8) assuring the all sample

custody procedures are followed. The sample collection completeness requirement for the benthic monitoring for the Chesapeake Bay Program is 90%. Current sample completeness record for all biological samples for this monitoring program is 100% and with respect to both field water quality and sediment samples, completeness is less than but nearly 100%.

The Chief Scientist is prepared on each cruise to accommodate any VADEQ or CBPO personnel that may audit the field collection procedures. On any cruise that an audit may be conducted the Chief Scientist will have available the QA/QC plan and will address all field activities as they relate to the objectives of the program.

5.0 LABORATORY PROCESSING

5.1 BIOLOGICAL SAMPLES

Benthic biological samples are sorted in white enamel pans with the aid of fiber optic illuminators. Animals are removed from the sediment residue, placed into pre-labeled 8 dram glass vials and preserved in alcohol until they are identified.

All specimens are identified to the lowest practical taxonomic level. For approximately 90% of the specimens this is the species level. Juvenile specimens are often difficult to identify to the specific level because they have not developed all of the characteristics used to identify adults. This is most often a problem with bivalves, certain polychaete families (e.g. Nephtyidae) and oligochaetes (where reproductive organs are the primary specific characters). In tidal freshwater areas, insect larvae (primarily the Chironomidae) are often poorly known and typically identification is to the generic level. All species counts are recorded on Lab Data Sheets (Figure 4). Species counts are recorded separately for each unpartitioned replicate and for each depth interval in partitioned replicates.

For biomass analysis, parts of individuals will be identified when possible. Broken tail ends of annelids and dropped appendages of crustaceans can often be identified as belonging to a dominant species. At each station/replicate/partition combination all individuals of each species are placed in labeled species-specific aluminum pans. All pans are then oven dried at 60^{o}C for at least 24 hr in a Boekel model 107801 drying oven. The drying oven is continually maintained at 60^{o}C and temperature periodically verified. Adjustments are made as necessary.

After drying, the pans are allowed to cool to room temperature and a dry weight is obtained. After a dry weight is obtained the pans are placed in a Thernolyne 62700 muffle furnace for 5 hr at 500^{o}C for ashing. Weight for each ashed sample is obtained in the same manner as for dry weight. The ash-free dry weight biomass (AFDW) is the difference between the dry and ash weights for each variable measured. Ash weights are measured to the nearest milligram (mg) using a Sartorius BP121S balance and recorded on Lab Data Sheets (Figure 4).

5.2 SEDIMENT SAMPLES

Sediment samples are stored in a BEL freezer until analyses are performed and each sample is defrosted and homogenized prior to analysis. Sediment analyses consist of two procedures: (1) particle size analysis and (2) organic content (volatile solids) analysis. Particle-size analysis measures is conducted using the techniques of Folk (1974). Each sediment sample is first separated into a sand fraction (> 63 μm) and a silt-clay fraction (< 63 μm) by wet sieving a 15 ml subsample through a 63 μm sieve screen using deionized water. The deionized water and fine particle mixture is retained in an enamel pan and then transferred to a labeled graduated cylinder. This portion of the sample is the silt-clay fraction. The cylinder is then filled to the 1000 ml mark, thoroughly mixed for at least one minute using a specially designed plunger and a single 20 ml pipette extraction is taken at 20 cm below the water's surface 20 s after mixing is stopped. The extraction is transferred to a pre-labeled and pre-dried 50 ml beaker which is then placed into a dryer oven until all of the water has evaporated. The beaker is then weighed using a Sartorius BP121S balance. Weight of the silt-clay fraction is calculated as the difference between 50 ml beaker after and before the extraction is added to the beaker multiplied by 50.

The sediment residue on the sieve is the sand fraction is transferred to a labeled glass preparation dish. If the sample has a large amount of detrital material, a small amount of chlorine bleach is added to digest organic detritus and then rinsed. After 24 hr the sample is rinsed on a 63 μm sieve, transferred to a new labeled dish and oven dried at 60°C for at least 12 hr. The sand fraction is then transferred to a pre-weighed plastic pan and weighed using a Sartorius BP121S balance. Weight of the sand fraction is calculated as the difference between the weight of the pan with and without the sand fraction. Percentages of the sand and silt-clay fraction are simply the weight each fraction divided by the sum of the silt-clay and sand fractions multiplied by 100.

Organic content (volatile solids) of the sediment is estimated as the ash-free dry weight of the sediment subsample expressed as a percentage of the dry weight of the sediment. Weights for pre-labeled aluminum pans are recorded for each station and a sediment subsample (approximately 10 ml) is placed in the appropriate pan. Dry weight and ash weight are determined for each sample (minus the pan weight) as per the biomass ash free dry weight (AFDW) method. All sediment data are recorded on Sediment Analysis Data Sheets along with the station number and date of collection.

5.3 LABORATORY SAMPLE CHAIN OF CUSTODY

Chain of custody for biological samples begins with sample sorting and is maintained throughout all sample processing procedures. After removing a sample from the sealed bucket containing the sample bags, each Laboratory Assistant (LA) must sign their name, identify the sample removed, the date the sample was removed for sorting and the date the sample was completed and record all this information on a Sample Processing Log sheet (Figure 3). The animals removed from the sediment residue during the sorting procedure are placed into pre-labeled 8 dram glass vials organized into specific spatial arrays in specially designed trays. Each label of the glass vials contains the same codes as the bag and must be matched by the LA prior to beginning the sorting

procedure. All sorted residues, the sample bag and the glass vials of organisms are checked by the BELS to ensure accuracy. The procedure is also used so that LAs are never aware of which samples will be selected for quality control checks.

Prior to beginning the identification procedure each Research Assistant (RA) must sign their name, identify the sample to be identified, the date the sample was removed for identification and the date the sample was completed and record all this information on a Sample Processing Log sheet (Figure 3). As each specimen is identified the complete scientific name is entered on a Lab Data Sheet (Figure 4) and the animal placed into a labeled aluminum pan for biomass analysis. The exact label on the glass vial is recorded on each weighing pan along with the station number, tributary, replicate number, and depth interval, if appropriate. In addition a unique code for each taxon identified is also placed on each weighing pan

The RAs place all the weighing pans from all replicates of a sampling station into the same enamel tray. All trays are immediately placed into the drying oven. All samples are tracked by their unique codes that now include the complete station code and the organism's taxonomic code. Upon completion of recording dry weights, trays are placed back into the drying oven prior to the ashing procedure. All weighing pans from the same sampling station are placed directly into the muffle furnace for ashing. After ashing, pans are reweighed and all data recorded on the BEL Lab Data Sheet containing the species count data for the corresponding station date replicate and partition.

The quality assurance/quality control (QA/QC) program at the BEL is designed to ensure that data of the highest quality possible for estimates of field parameters are being generated and transferred to the funding agency. The fundamental parameter being measured in any biological monitoring program is what species are present (Ellis 1988). "The fundamental accuracy in biological surveys is getting the species identification right, getting the correct Linnean name, and doing so consistently" (Ellis 1988, p. 507). Indeed, all other estimates of field parameters (e.g., densities and biomass of populations) can not truly be tested for accuracy because standards are meaningless. Accuracy can only be approximated by inter-laboratory calibrations (see e.g. Ellis and Cross 1981) which are not part of the present program because (1) accepted protocols do not exist and (2) fiscal resources are limited.

5.4 LABORATORY SAMPLE DATA QUALITY OBJECTIVES

The QA/QC program is designed to manage sample handling, documentation and custody, proper data generation, and quality control actions. The QA/QC program tracks and monitors the fate of a sample from collection to data submission and analysis assuring that the proper samples have been analyzed by the appropriate methods and that necessary QC measures have been taken to ensure that data of definable quality have been produced.

A total of 10% of all samples are re-sorted and checked for sorting accuracy while all samples are given a cursory examination. Training of sorters consists of verifying 100% of samples sorter by any individual sorter until a level of proficiency is reached which is deemed acceptable by th BELS.

For all parameters measured a discrepancy of less than 5.0% from re-analyzed samples is considered acceptable, except for estimates of weight, where a discrepancy of less than 2 mg from re-analyzed samples is considered acceptable. A total of 10% of all biological samples are re-analyzed for accuracy by the BELS.

Although 90% sample completeness is the minimum standard required by the Chesapeake Bay Program, sample processing completeness is to date 100% for all biological parameters measured for any given sampling cruise. Completeness for sedimentary data is also > 90%.

Internal audits of all laboratory activities are conducted once each year by the Program Manager. The PM reviews all procedures with the BELS as detailed in the SOPs The BEL is prepared to participate in external audits by personnel of the VADEQ or the CBPO.

6.0 DATA MANAGEMENT

Data transcription, verification and reporting procedures are designed to produce data sets that meet the submittal requirements for the USEPA's Chesapeake Bay Program Baywide Benthic Database and have been verified as exactly reproducing all information from each Field Data Sheet (Figure 2), Lab Data Sheet (Figure 4) or Sediment Analysis Sheet (Figure 5).

All data from the Field Data, Lab Data and Sediment Analysis sheets are entered into the Benthic portion of the Chesapeake Bay Program at ODU Living Resources Database (Figure 6). This is a Microsoft FoxPro relational database program that allows for easy data entry, verification, and retrieval. The database can produce text, Excel or ASCII files including submittal files for the EPA Chesapeake Bay Program. This is a unique data entry program that was written to eliminate data entry errors on all BEL projects. The use of this program requires no programming skills and has numerous places during data entry that require data verification.

Data are entered, verified, stored, and exported for submittal using this system. The program and associated data tables are stored on a Novell network server connect to Old Dominion University's wide area network. This system allows for automatic backup of all files and data associated with this program at a minimum on a weekly basis. Data are also directly retrieved from the database system to create a variety of long-term SAS data sets used for data analysis and reporting requirements. Long-term SAS data bases are also stored on a Novell network server connect to Old Dominion University's wide area network and receive regular backups.

7.0 DATA ANALYSIS

Routine assessments of the current status of and long-term trends in water quality and living resource conditions in Chesapeake Bay are made on an annual basis. A unified approach for conducting the statistical analyses and interpreting their results was developed and is used for all monitoring components and jurisdictions for the Chesapeake Bay Program. The procedures used and presented below are based on general guidelines and recommendations developed for all monitoring programs by the CBP Monitoring Subcommittee's Tidal Monitoring and Assessment

Workgroup (TMAW) with some modifications adopted to accommodate differences in the sampling regime and parameters measured that are specific to the benthic biological monitoring program. Any modifications or additions to existing protocols are made with prior approval of the US EPA Chesapeake Bay Program.

7.1 THE B-IBI AND THE CHESAPEAKE BAY BENTHIC COMMUNITY RESTORATION GOALS

The B-IBI is a multiple-attribute index developed to identify the degree to which a benthic assemblage meets the Chesapeake Bay Program Benthic Community Restoration Goals (Ranasinghe et al. 1994, updated by Weisberg et al. 1997; Alden et al. 2002). The B-IBI provides a means for comparing relative condition of benthic invertebrate assemblages across habitat types. It also provides a validated mechanism for integrating several benthic community attributes indicative of habitat "health" into a single number that measures overall benthic community condition.

The Restoration Goals are quantitative expectations (e.g., abundance, biomass, or diversity values) based on relatively unimpacted benthic communities in Chesapeake Bay. Benthic data from several different monitoring programs were standardized to allow their integration into a single, coherent data base. From that data base a set of benthic community attributes and threshold values (the Goals) was developed to describe characteristics of benthic assemblages expected at sites having little evidence of environmental stress or disturbance. Measures used in Restoration Goal development were of five types: diversity, abundance and biomass, life history, activity beneath the sediment surface, and feeding guilds. Using these goals, benthic data from any part of the Bay could be compared to determine whether conditions at a site met, were above, or were below expectations defined for reference sites in similar habitat types. The Restoration Goals were developed for the worst-case scenario, the summer period (July 15 to September 30), when benthic communities are expected to show the greatest response to low dissolved oxygen and pollution stress.
The B-IBI is scaled from 1 to 5; sites with values of 3 or more are considered to meet the Restoration Goals. The index is calculated by scoring each of several attributes as either 5, 3, or 1 depending on whether the value of the attribute at a site approximates, deviates slightly from, or deviates strongly from values found at the best reference sites in similar habitats, and then averaging these scores across attributes. The criteria for assigning these scores are numeric and depend on habitat. The application is presently limited to summer samples; data from time periods for which the B-IBI has not yet been developed are not used for B-IBI based assessment.

Benthic community condition is classified into four levels based on the B-IBI. Values less than or equal to 2 are classified as severely degraded; values from 2 to 2.6 are classified as degraded; values greater than 2.6 but less than 3.0 are classified as marginal; and values of 3.0 or more are classified as meeting the goals. Values in the marginal category do not meet the Restoration Goals, but they differ from the goals within the range of measurement error typically recorded between replicate samples.

7.2 FIXED SITE STATUS AND TREND ANALYSIS

Long-term trend analyses used to assess changes in benthic community conditions over time are conducted using the B-IBI and selected component metrics of the B-IBI including species diversity (H'), community abundance, community biomass, pollution-indicative species abundance, pollution-indicative species biomass, pollution-sensitive species abundance, and pollution-sensitive species biomass. See Weisberg et al. (1997) for a list of pollution-indicative and pollution-sensitive taxa. The statistical test used for is the Mann-Kendall non-parametric test for monotonic trends (Gilbert, 1987). Slope of the trend line is determined by calculating Sen's non-parametric slope estimator (Gilbert, 1987). For the benthic bioindicators the statistical test criterion was a *P* value of 0.10. All trend analyses were conducted using programs developed in SAS/Base and SAS/Stat programming software under the direction of the US EPA Chesapeake Bay Program. All trend analyses are conducted separately for each station using all observations collected during the July 15 through September 30 index period. Status of benthic communities at each fixed point monitoring station is characterized using the three-year mean value of the B-IBI as described in Section 7.1.

7.3 PROBABILITY-BASED ESTIMATION

Status of benthic communities is also quantified at the stratum level using the probability-based sampling data to estimate the bottom area populated by benthos that meet the Chesapeake Bay Benthic Community Restoration Goals (Ranasinghe et al. 1994; Weisberg et al. 1997). This approach produces an estimate of the spatial extent and distribution of degraded benthic communities in Chesapeake Bay (Dauer and Llansó 2003; Llansó et al. 2003). To estimate the amount of area in the entire Bay that failed to meet the Chesapeake Bay Benthic Restoration Goals (P), each site *I* in a given stratum *h* is assigned a value, *y*, of 1 if the goals are met and 0 otherwise. For each stratum, the estimated proportion of area meeting the goals, p_h, and its variance were calculated as the mean of the y_{hi}'s as follows:

$$p_h = \overline{y}_h = \sum_{i=1}^{n_h} \frac{y_{hi}}{n_h},$$

Variance for this estimate is calculated as:

$$\text{var}\ (p_h) = s_h^2 = \sum_{i=1}^{n_h} \frac{(y_{hi} - \overline{y}_h)^2}{n_h - 1}.$$

Estimates for strata can be combined to estimates of areal degradation for larger areas (e.g. all Virginia waters or the entire Chesapeake Bay) as:

$$P_{ps} = \overline{y}_{ps} = \sum_{h=1}^{10} W_h \overline{y}_h,$$

were the weighting factors, W_h, = A_h/A and A_h were the total area of the *h*th stratum. The variance of (3) was estimated as:

$$\text{var}\ (P_{ps}) = V(\overline{y}_{ps}) = \sum_{h=1}^{10} W_h s_h^2 / n_h.$$

For combined strata, the 95% confidence intervals were estimated as the proportion plus or minus twice the standard error. For individual strata, the exact confidence interval is determined from tables.

7.4 REPORTING

Progress Reports (PR) are produced for each collection cruise which includes a narrative summary of any problems encountered in data collection and summary tables for (1) the physical data, (2) sedimentary data, (3) total community parameters, (3) numbers of individuals per station, (4) ash-free dry weight biomass by station, (5) depth distribution by station and (6) an updated list of all taxa collected in the monitoring program.

For the probability-based sampled strata a final report (PBFR) is produced within 120 days of completion of field collection (July 15 to September 30). The PBFR includes a narrative summary of any problems encountered in data collection and includes summary tables for (1) the physical data, (2) sedimentary data, (3) total community parameters, (3) numbers of individuals per station, (4) ash-free dry weight biomass by station, (5) an updated list of all taxa collected in each stratum, and (6) an estimate of condition of the benthos within each stratum through application of the Benthic Restoration Goals and the Benthic Restoration Goals Index.

When appropriate resources are provided by DEQ the data summaries and analyses are provided to the DEQ as needed for various reports. These reports may include a variety of analyses and statistics for all data collected from the fixed-point stations sampled in September of each year. Reports of this type often include long-term trend analyses as described above along with status

assessments at fixed point stations and areal assessments of restoration goal attainment as described above.

8.0 REFERENCES AND LITERATURE CITED

Alden, R.W. III, D.M. Dauer, J.A. Ranasinghe, L.C. Scott, and R.J. Llansó. 2002. Statistical Verification of the Chesapeake Bay Benthic Index of Biotic Integrity. *Environmetrics*13: 473-498.

Bilyard, G.R. 1987. The value of benthic infauna in marine pollution monitoring studies. Mar. Poll. B18: 581-585.

Dauer, D.M. and R. J. Llansó. 2003. Spatial scales and probability based sampling in determining levels of benthic community degradation in the Chesapeake Bay. *Environmental Monitoring and Assessment* 81: 175-186.

Ellis, D.V. 1988. Quality control of biological surveys. Mar. Poll. Bull. 19: 506-512.

Ellis, D.V. and S.F. Cross. 1981. A protocol for inter-laboratory calibrations of biological species identification (Ring Tests). Water Res. 15: 1107-1108.

Folk, R.L. 1974. Petrology of sedimentary rocks. Hemphill Publishing Co., Austin, Texas, 182 pp.

Gilbert, R.O. 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold Co., New York, 320 pp.

Llansó, R.J., D.M. Dauer, J.H. Vølstad, and L.S. Scott. 2003. Application of the Benthic Index of Biotic Integrity to environmental monitoring in Chesapeake Bay. *Environmental Monitoring and Assessment* 81: 163-174.

Ranasinghe, J.A., S.B. Weisberg, D.M. Dauer, L.C. Schaffner, R.J. Diaz and J.B. Frithsen. 1994. Chesapeake Bay benthic community restoration goals. Chesapeake Bay Program, U.S. Environmental Protection Agency. CBP/TRS 107/94. Annapolis, Md. 49 pp.

Van Belle, G. and J.P. Hughes. 1984. Nonparametric tests for trend in water quality. Water Resources Research 20: 127-136.

Weisberg, S.B., A.F. Holland, K.J. Scott, H.T. Wilson, D.G. Heimbuch, S.C. Schimmel, J.B. Frithsen, J.F. Paul, J.K. Summers, R.M. Valente, J. Gerritsen, and R.W. Latimer. 1993. EMAP-Estuaries, Virginian Provinence 1990: Demonstration Project Report. EPA/600/R-92/100. U.S. Environmental Protection Agency, Washington, D.C.

Weisberg, S.B., J.A. Ranasinghe, D.M. Dauer, L.C. Schaffner, R.J. Diaz and J.B. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. *Estuaries* 20: 149-158.

U. S. Environmental Protection Agency. 1983. Chesapeake Bay: A framework for action. Prepared for the U. S. Congress by the Environmental Protection Agency, Region 3, Philadelphia, Pa.

Tables

Table 1. Location of sampling stations in the lower Chesapeake Bay Benthic Biological Monitoring Program.

STATION	DESCRIPTION	LATITUDE (NAD83)	LONGITUDE (NAD83)
CB5.4	Main Bay, Upper	37.7999	-76.1742
CB6.1	Main Bay, Off Rappahannock R.	37.5893	-76.1602
CB6.4	Main Bay, Off York River	37.2370	-76.2021
CB7.3E	Main Bay, Off Old Plantation Fl.	37.2553	-76.0526
CB8.1	Main Bay, Off James River	36.9852	-76.1664
LE3.2	Rappahannock River Upstream Buoy R8	37.6701	-76.5551
LE3.4	Rappahannock River, Orchard Pt.	37.6335	-76.4652
LE4.1	York River, N44	37.4183	-76.6933
LE4.3	York River, off VIMS, shoal	37.2430	-76.4861
LE4.3B	York River, off VIMS, channel	37.2311	-76.4743
LE5.1	James River, Buoy C 12-13	37.2103	-76.7046
LE5.2	James River, Buoy 9	37.0574	-76.5914
LE5.4	Rappahannock River, N Buoy R10	36.9534	-76.3916
RET3.1	Rappahannock River, Buoy 10	37.9209	-76.8204
RET4.3	York River, C57, Below West Point	37.5114	-76.7884
RET5.2	James River, Swann's Point	37.2129	-76.7930
SBE2	Elizabeth R. off Atl. Wood	36.8136	-76.2897
SBE5	Elizabeth R. off VEPCO	36.7690	-76.2983
TF3.3	Rappahannock River, N40	38.0185	-76.9089
TF4.2	Pamunkey River at White House	37.5464	-76.9743
TF5.5	James River, Red Buoy 10	37.3131	-77.2311

Figures

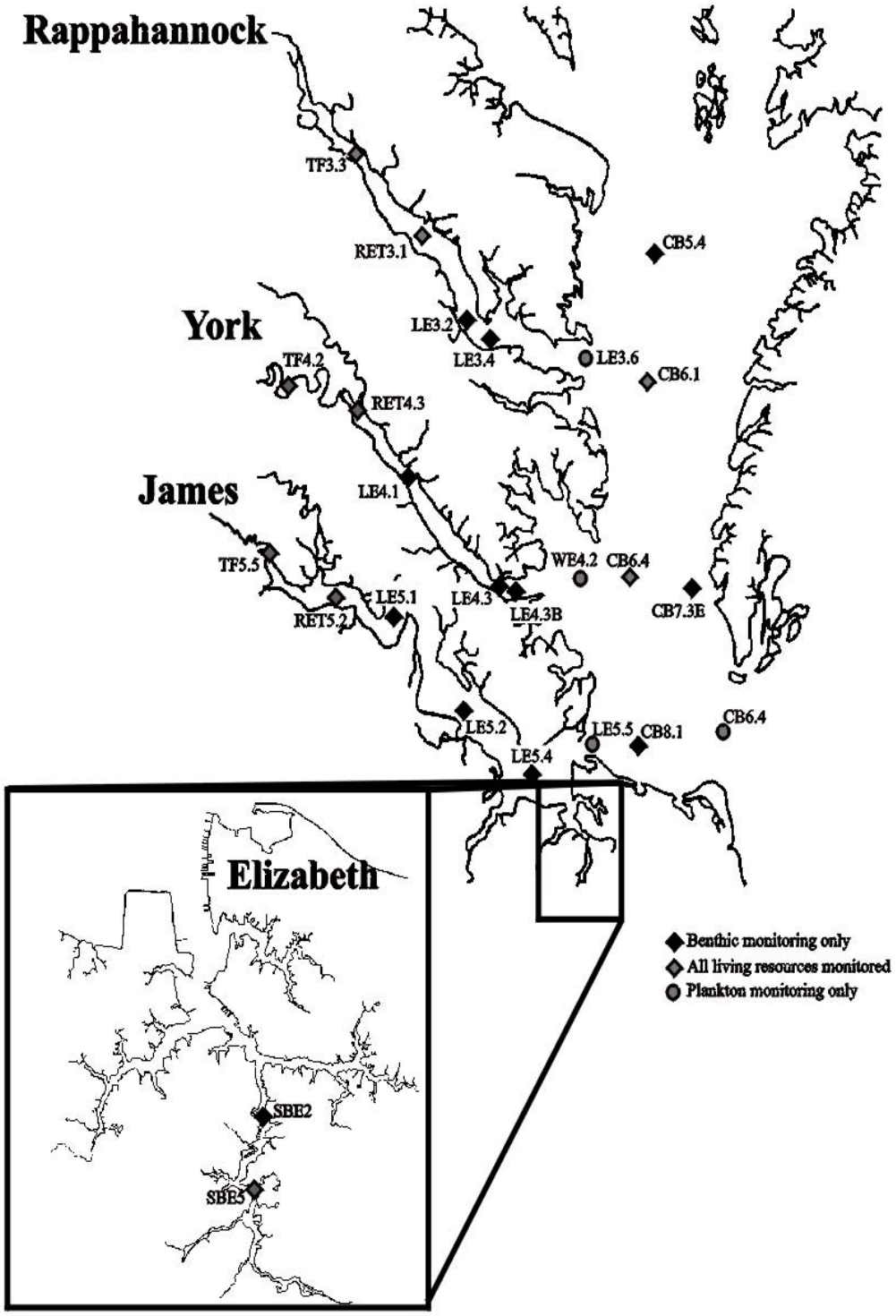

Figure 1. Map of stations in the lower Chesapeake Bay. See Table 1 for station coordinates.

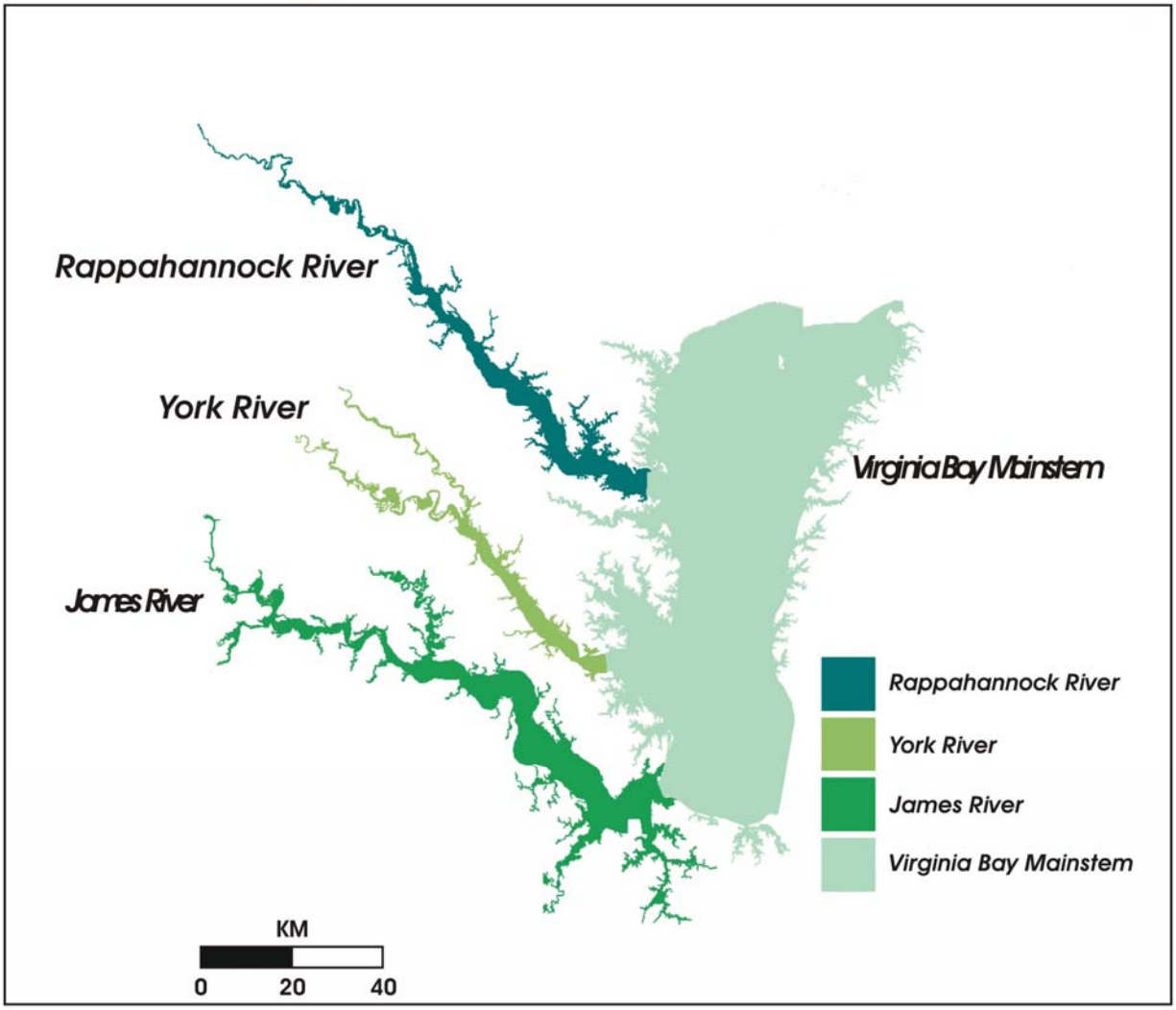

Figure 2. Virginia baywide sampling strata

Field Data Sheet _____(Year/Cruise)____

STATION	DATE	TIME	DEPTH(F)	TEMP ^{o}C	SALINITY	D.O.	COMMENTS

Figure 3. Field Data Sheet.

Sample Processing Log Sheet -- Cruise _____

STATION	SORTER	START DATE	END DATE	TIME SPENT	COMMENTS

Figure 4. Sample Processing Log.

Program	Year	Cruise	Site	Depth	Total Count	Species

Species Code	Species	Count		Dry Weight		Ash Weight
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					

Comments:

_____

_____

_____

_____

_____

QA/QC LOG FOR SAMPLE PROCESSING PROJECT: YEAR: CRUISE:

SAMPLE	SORTER (Name/Date)	QC TYPE (Sorting/ID)	QC BY (Name/Date)	COMMENTS

Figure 6. Quality Control Log.

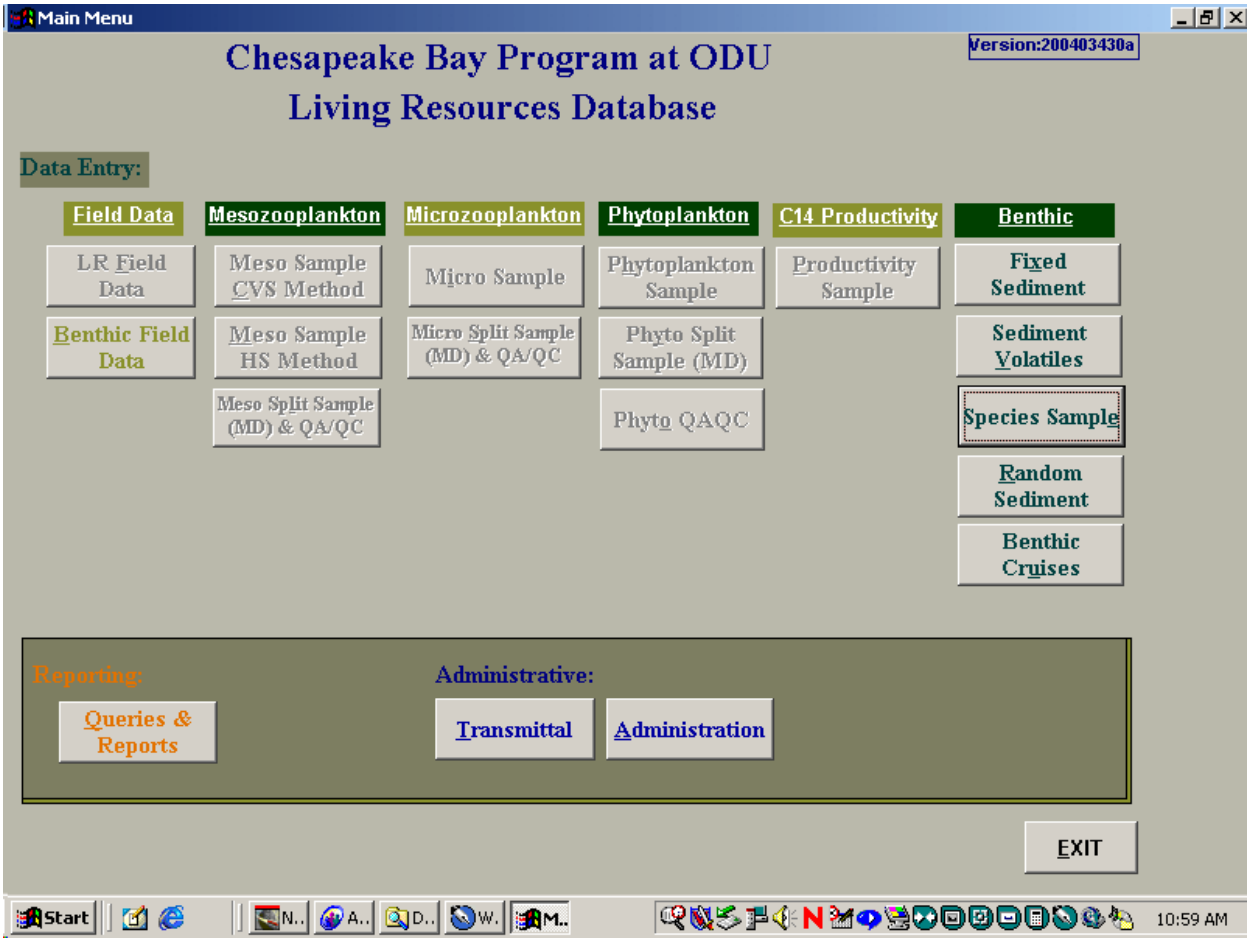

Figure 7. Living resources database system.

Appendix

Chesapeake Bay Benthic Monitoring Program

Sampling Regime Changes

1. Fixed station monitoring program

In March 1985, the Chesapeake Bay Benthic Monitoring Program began with 16 stations sample quarterly (March, June, September, December) using a box core. All stations had three replicates. The third replicate was partitioned into six depth intervals of 0-2 cm, 2-5 cm, 5-10 cm, 10-15 cm, 15-20 cm and 20-25 cm.

Original 16 Stations

CB7.3E
CB5.4
CB6.1
CB6.4
LE3.2
RET3.1
TF3.3
LE4.1
LE4.3
RET4.3
TF4.2
CB8.1
LE5.2
LE5.4
RET5.2
TF5.5

In December 1986, five (5) additional stations were sampled quarterly with the box core through September 1987.

Stations sampled
12/1986 - 09/1987

CB5.5
CB6.2
CB7.1S
CB7.2
LE3.4

In September 1988, three (3) stations were added to the quarterly box core sampling. One of theses stations, LE3.4, had previously been sampled for the four quarters from December 1986 through September 1987.

Stations added September 1988

LE3.4
LE5.1
LE4.3B

In September 1989, two stations in the Southern Branch of the Elizabeth River were added to the quarterly box core sampling bringing the total number of fixed samples to 21. These two stations remain part of the current fixed sampling program.

Stations added September 1989
SBE2
SBE5

In March 1994, one station was added at the mouth of the Rappahannock River - LE3.4B. This station was sampled for two years until it was discontinued after the December 1995 sampling period.

Station sampled March 1994 – December 1995
LE3.4B

Beginning in 1996, the fixed box core sampling at all stations 21 was reduced from four quarterly samples a year to twice a year - June and September. At the same time a random benthic sampling program was initiated (see below).

Beginning in 1999, the number of partitions for the third replicate was reduced to two intervals; 0-5 cm and 5-25 cm.

In 2004, the sampling frequency at all 21 fixed stations was reduced to once per year with sampling restricted to the same time window as the random sampling program i.e. July 15 through September 30.

2. Random station monitoring program

Beginning in 1996, 100 random benthic stations are sampled each year as part of a probabilistic sampling program. Samples are allocated evenly across and distributed randomly within four strata; the James River, York River, Rappahannock River and the Virginia portion of the main stem, for a total of 25 stations in each stratum. These stations are sampled, one replicate each, with the Young sampling gear. Sampling occurs once each year; between July 15 through September 30.

In 2004, in order assess any differences between the Yong Gear and two petite ponar samples, an additional ten (10) randomly selected stations were sampled in each of three strata; the Nansmond River, Mobjack Bay and the tidal freshwater portion of the Mattaponi River.

In 2005 and 2006, a subset of the random samples (n= 19 and n=21 respectively) were co-sampled as part of the National Coastal Assessment program. An additional 31 (2005) and 29 (2006) were collected by Virginia DEQ personnel. The community analysis for these additional NCA stations was completed by the Old Dominion University Benthic Ecology Laboratory (BEL). In 2007, 50 NCA stations were collected by Virginia DEQ personnel. The community analysis for these stations was also completed by the BEL. All stations samples collected by VA DEQ personnel were the composite of two separate petite ponar samples.

In 2006, a total of 28 additional random stations were collected with the Young gear in five substrata; CHKOH, CRRMH, JMSTF1, PMKTF, and RPPOH. Theses samples were collected to assist with the impaired waters report.

3 Taxonomic name changes

Table A-1 lists the changes in taxonomic names used in the Chesapeake Bay Benthic Monitoring Program by the Benthic Ecology Laboratory at Old Dominion University from its inception in 1985 through the present. Name changes may be the result of misspellings, synonymies, re-descriptions, grouping or ungrouping of species complexes. The table displays the currently used taxon name, previously used taxon name, the date when the previous name was first used and last used.

Table A-1. List of changes in taxonomic names used in the Chesapeake Bay Benthic Monitoring Program by the Benthic Ecology Laboratory at Old Dominion University from its inception in 1985 through the present. The table displays the currently used taxon name; previously used taxon name, the date when the previous name was first used and last used.

Current Taxon Name	Previous Taxon Name	First Date	Last Date
Ablabesmyia parajanta	Ablabeymia parajanta	19-Mar-88	16-Aug-01
Ablabesmyia parajanta	Albabesmyia parajanta	13-Mar-85	1-Apr-86
Aegathoa medialis	Aegathoa medialis?	19-Jun-91	13-Sep-04
Americamysis bigelowi	Mysidopsis bigelowi	25-Sep-86	25-Aug-04
Americhelidium americanum	Synchelidium americanum	18-Jun-90	8-Aug-01
Ameroculodes species complex	Monoculodes edwardsi	27-Jun-85	27-Sep-01
Ameroculodes species complex	Monoculodes intermedius	14-Mar-85	31-Aug-00
Ampelisca spp.	Ampelisca spp. juveniles	19-Dec-86	23-Feb-96
Anachis translirata	Anachis translinata	19-Dec-86	23-Mar-93
Apocorophium acutum	Corophium acutum	17-Mar-88	27-Sep-01
Apocorophium lacustre	Corophium lacustre	13-Mar-85	15-Sep-04
Apocorophium simile	Corophium simile	13-Mar-85	27-Sep-01
Arabella iricolor-multidentata complex	Arabella iricolor	15-Dec-85	23-Jul-98
Argulus spp.	Argulus sp.	21-Jun-86	25-Sep-86
Asellus spp.	Ascellus spp.	3-Aug-04	3-Aug-04
Astyris lunata	Mitrella lunata	16-Mar-85	13-Sep-00
Balanoglossus aurantiacus	Balanoglossus auranticus	16-Dec-85	21-Feb-96
Bhawania heteroseta	Paleanotus heteroseta	12-Mar-85	27-Sep-01
Biffarius biformis	Callianassa biformis	16-Dec-86	18-Sep-00
Boccardiella hamata	Boccardia hamata	19-Dec-87	26-Sep-96
Boonea bisuturalis	Odostomia bisuturalis	16-Mar-85	16-Mar-85
Brachyura spp.	Brachyura	1-Aug-02	29-Jul-05
Branchiostoma caribaeum	Branchiostoma virginae	26-Jun-02	15-Sep-04
Branchiostoma caribaeum	Branchiostoma virginiae	16-Mar-87	28-Sep-01
Brania wellfleetensis	Brania welfleetensis	26-Jun-85	1-Sep-04
Busycon spp.	Busycon sp. (juveniles)	29-Jun-85	17-Jul-00
Cabira incerta	Cabira incorta	15-Dec-86	15-Dec-86
Capitella capitata complex	Capitella capitata	26-Jun-85	17-Aug-04
Capitellides jonesi	Capitella jonesi	4-Mar-89	13-Aug-99
Cassidinidea ovalis	Cassidinidea lunifrons	18-Sep-85	14-Sep-04
Caulleriella sp. B (Blake)	Caulleriella killariensis	13-Mar-85	13-Sep-04
Caulleriella spp.	Caulleriella sp. A	26-Sep-96	4-Aug-97
Cerapus tubularis	Cerapes tubularis	12-Jun-95	14-Jun-95
Ceriantheopsis americanus	Cerianthus americanus	15-Dec-85	9-Aug-04
Chiridotea coeca	Chirodotea coeca	15-Dec-85	21-Dec-89
Chiridotea nigrescens	Chirodotea nigrescens	25-Jun-85	13-Jun-95

Table A-1 (continued).

Current Taxon Name	Previous Taxon Name	First Date	Last Date
Chiridotea spp.	Chirodotea spp.	18-Dec-90	18-Dec-90
Chironomidae spp.	Chironomidae spp. larvae	11-Jun-88	10-Aug-99
Cirrophorus lyriformis	Cirrophorous lyriformis	3-Sep-93	7-Aug-06
Corbicula fluminea	Corbicula manilensis	24-Sep-86	19-Sep-01
Cricotopus spp.	Cricotopus sp.	16-Dec-86	18-Mar-88
Cryptochironomus parafulvus	Cryptochironomous parafulvus	1-Dec-89	13-Jun-95
Cyathura burbancki	Cyathura burbanki	4-Aug-97	15-Jul-04
Demonax microphthalmus	Sabella microphthalma	14-Mar-85	27-Sep-01
Dipolydora caulleryi	Polydora caulleryi	16-Dec-85	9-Aug-00
Dipolydora socialis	Polydora socialis	18-Jun-90	4-Jun-96
Djalmabatista pulcher	Djalmabetista pulcher	15-Mar-91	15-Mar-91
Donax variabilis	Donax variablis	15-Jul-04	15-Jul-04
Dorvillea rudolphi	Schistomeringos rudolphi	17-Sep-85	19-Sep-01
Dulichiella appendiculata	Melita appendiculata	27-Sep-86	27-Sep-01
Dyspanopeus sayi	Neopanope sayi	15-Dec-85	8-Mar-95
Elasmopus laevis	Elasmopus levis	19-Jun-87	6-Jun-01
Eobrolgus spinosus	Paraphoxus spinosus	26-Jul-06	26-Jul-06
Ephemeroptera spp.	Ephemeroptera	19-Aug-03	19-Aug-03
Ephemeroptera spp.	Ephemoptera spp.	15-Jan-90	15-Jan-90
Epitonium spp.	Epitonium sp.	16-Mar-85	23-Sep-97
Ericthonius brasiliensis	Erichthonius brasiliensis	12-Mar-85	15-Jul-04
Euclymene zonalis	Macroclymene zonalis	12-Mar-85	13-Sep-04
Gammarus spp.	Gammarus sp.	13-Mar-85	5-Sep-96
Genetyllis castanea	Phyllodoce castanea	20-Sep-85	4-Mar-89
Gilvossius setimanus	Callianassa atlantica	25-Sep-86	18-Sep-01
Glycera robusta	Glycera robustus	10-Jun-02	10-Jun-02
Glyptotendipes spp.	Glycotendipes spp.	11-Jan-89	11-Jan-89
Gyptis crypta	Gyptis vittata	26-Jun-85	16-Aug-00
Harmothoe spp.	Harmothoe sp. A	15-Dec-86	14-Sep-95
Hesionura elongata	Hessionura elongata	23-Aug-99	23-Aug-99
Hirudinea spp.	Hirudinea sp.	25-Sep-87	4-Aug-04
Hutchinsoniella macracantha	Hutchinoniella macracantha	13-Sep-04	1-Aug-05
Hutchinsoniella macracantha	Cephalocarid spp.	18-Dec-87	22-Sep-97
Hydrobiidae spp.	Hydrobidae spp.	24-Jul-96	4-Aug-04
Hydrobiidae spp.	Hydrobia spp.	10-Mar-94	25-Jun-97
Hydropsyche spp.	Hydrpsyche spp.	21-Sep-94	21-Sep-94
Incisocalliope aestuarius	Parapleustes aestuarius	29-Jun-85	11-Mar-94
Kurtziella atrostyla	Kurtziella astrostyla	7-Dec-94	17-Jul-00
Leptognathia caeca	Leptognatha caeca	7-Aug-06	7-Aug-06
Leptognathia caeca	Leptognatha caeca	9-Aug-02	9-Aug-02

Table A-1 (continued).

Current Taxon Name	Previous Taxon Name	First Date	Last Date
Leucothoidae spp.	Leucothoidea spp.	20-Aug-01	6-Sep-01
Limnodrilus spp. juv.	Limnodrilus sp. juv.	26-Jul-96	2-Oct-03
Limnodrilus spp. juv.	Limnodrilus sp. (juv.)	13-Mar-85	27-Sep-01
Limnodrilus spp. juv.	Limnodrilus spp. (juveniles)	13-Mar-85	19-Mar-87
Listriella bowenae	Idunella bowenae	24-Jun-97	15-Jun-00
Listriella smithi	Idunella smithi	16-Dec-87	3-Jun-98
Listriella spp.	Idunella sp.	15-Dec-85	18-Jun-91
Magelona spp.	Magelona sp.	26-Jun-85	13-Sep-04
Malmgreniella taylori	Malmgrenia lunulata	7-Dec-94	27-Sep-01
Manayunkia aestuarina	Manayunkia speciosa	14-Dec-94	7-Jun-99
Marenzelleria viridis	Scolecolepides viridis	13-Mar-85	25-Jun-97
Marphysa sanguinea	Marphysa sanquinea	30-Jul-99	16-Jul-03
Microphiopholis atra	Amphiodia atra	19-Sep-85	27-Sep-01
Microphthalmus spp.	Microphthalmus sp.	9-Aug-99	14-Aug-03
Monocorophium acherusicum	Corophium acherusicum	14-Mar-85	13-Sep-01
Monocorophium insidiosum	Monocorophium insosidi	5-Aug-02	5-Aug-02
Monocorophium insidiosum	Corophium insosidium	8-Jun-89	5-Sep-01
Monocorophium tuberculatum	Corophium tuberculatum	26-Jun-85	27-Sep-01
Monticellina dorsobranchialis	Monticellina dorsobrancialis	10-Jun-02	7-Aug-06
Monticellina dorsobranchialis	Tharyx annulosus	14-Mar-85	19-Sep-01
Mucrogammarus mucronatus	Gammarus mucronatus	26-Sep-86	14-Aug-00
Mytilopsis leucophaeata	Mytilopsis leucophaeta	24-Jul-96	15-Sep-04
Nassarius trivittatus	Nassarius trivittatu	14-Aug-03	8-Sep-03
Neanthes arenaceodentata	Nereis acuminata	13-Aug-96	27-Sep-01
Neanthes succinea	Nereis succinea	12-Mar-85	27-Sep-01
Nephtys spp.	Nephtys sp.	26-Jun-85	2-Jun-98
Nereididae sp. A	Nereidae sp. A	15-Dec-86	1-Aug-05
Nereididae spp.	Nereidae spp.	17-Jun-92	17-Jun-92
No Organisms Present	No Organisms Found	11-Jun-02	15-Sep-04
No Organisms Present		7-Jun-01	20-Sep-01
Notomastus sp. A Ewing	Notomastus sp.	12-Mar-85	19-Sep-01
Odostomia spp.	Odostomia sp. a	15-Dec-86	15-Dec-86
Oligochaeta spp.	Oligochaeta sp. M	26-Sep-96	28-Sep-01
Oligochaeta spp.	Oligochaeta sp A(serrate chaetae)	20-Jun-90	20-Jun-90
Oligochaeta spp.	Oligochaeta sp. X (no setae)	20-Sep-85	20-Sep-85
Onchidoris aspersa	Onchidoris aspera	16-Jun-97	16-Jun-97
Orbiniidae spp.	Orbiniid spp. (juveniles)	13-Mar-85	14-Mar-95
Palaemonetes pugio	Palaeomonetes pugio	19-Sep-95	1-Aug-00
Parahaustorius longimerus	Parahaustorious longimerus	4-Aug-97	4-Aug-97
Paranais frici	Wapsa mobilis	2-Mar-89	2-Mar-89
Paranais litoralis	Paranais littoralis	16-Jul-03	4-Sep-03

Table A-1 (continued).

Current Taxon Name	Previous Taxon Name	First Date	Last Date
Paratendipes spp.	Paratendipes sp.	18-Mar-87	18-Mar-87
Parougia caeca	Schistomeringos caeca	27-Sep-86	20-Dec-89
Pentamera pulcherrima	Pentamera pulcherima	20-Dec-89	13-Sep-94
Phoronis spp.	Phoronis psammophila	12-Mar-85	28-Sep-01
Photis pollex	Photis macrocoxa	16-Mar-87	8-Aug-02
Photis pugnator	Photis reinhardi	16-Mar-87	5-Aug-98
Photis spp.	Photis sp.	15-Dec-86	4-Aug-97
Phyllodoce spp.	Phyllodoce sp. (juveniles)	27-Jun-85	8-Jun-89
Pisidium spp.	Pisidium sp.	28-Jun-85	4-Aug-04
Platynereis dumerilii	Platynereis dumerili	5-Aug-03	5-Aug-03
Pleustidae spp.	Pleustidae sp.	9-Mar-90	9-Mar-90
Podarkeopsis levifuscina	Gyptis brevipalpa	12-Mar-85	28-Sep-01
Polinices duplicata	Polinices duplicatus	18-Mar-87	18-Sep-01
Polychaeta spp.	Polychaete Fragments	12-Mar-85	17-Sep-85
Polydora cornuta	Polydora ligni	13-Mar-85	27-Sep-01
Polynoidae spp.	Polynoidae sp.	29-Jun-85	19-Mar-87
Proceraea spp.	Proceraea sp.	6-Jun-89	12-Jun-95
Pseudeurythoe paucibranchiata	Pseudeurythoe ambigua	12-Mar-85	20-Sep-01
Pseudochironomus fulviventris	Psuedochironomus fulviventris	21-Jun-90	26-Jul-00
Pseudochironomus fulviventris	Psuedochironomous fulviventris	2-Mar-89	2-Mar-89
Pseudopotamilla reniformis	Potamilla reniformis	8-Dec-94	25-Aug-97
Sabaco elongatus	Asychis elongata	13-Mar-85	20-Sep-01
Sabellides octocirrata	Sabellides octocirra	8-Jun-89	8-Jun-89
Scolelepis spp.	Scolelepis sp.	21-Jun-90	10-Aug-99
Scoletoma fragilis	Lumbrineris fragilis	24-Sep-86	24-Sep-86
Scoletoma tenuis	Lumbrineris tenuis	8-Jun-94	17-Aug-00
Spiochaetopterus costarum	Spiochaetopterus oculatus	26-Jun-85	27-Sep-01
Stenothoe spp.	Stenothoe sp.	15-Dec-85	8-Aug-02
Tagelus plebeius	Tagelus plebeuis	7-Jan-89	3-Oct-89
Tanytarsini spp.	Tanytarsini sp.	18-Sep-85	11-Sep-03
Thalassema hartmani	Thalassema sp.	15-Dec-86	20-Sep-01
Trichoptera spp.	Trichoptera sp.	13-Mar-85	18-Sep-01
Tubificoides spp.	Tubificoides sp. A	27-Jun-85	27-Jun-85
Tubificoides spp.	Tubificoides sp. B	27-Jun-85	27-Jun-85
Tubificoides spp.	Tubificoides spp	12-Mar-85	14-Aug-00
Turbellaria spp.	Turbellaria sp. 1 (Pigmented Form)	18-Mar-88	18-Mar-88
Turbellaria spp.	Turbellaria sp. 1 (Round Pigmented Form)	12-Mar-85	16-Mar-85
Websterinereis tridentata	Websternereis tridentata	21-Jun-86	21-Jun-86

Table A-1 (continued).

Current Taxon Name	Previous Taxon Name	First Date	Last Date
Xenochironomus festivus	Xenochironomous festivus	15-Jan-90	15-Jan-90
Xenochironomus spp.	Xenochironomous spp.	7-Jan-89	3-Oct-89
Yoldia spp.	Yoldia sp.	5-Jan-89	5-Jan-89

Data analysis changes

Beginning in 2006, the sediment particle size analysis was modified to measure only percent sand and percent silt-clay. Mean phi size, skewness and kurtosis were no longer measured.